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Protection of Wood from Burning with Paints on Alkaline Aluminosilicates-Based

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Abstract. The aim of the work was to determination the combustibility group of color fire retardant paints for wood. As a result of the fire tests, it was found that the developed compositions of fire-retardant mineral paints on an alkaline aluminosilicate binder in the $(Na, K)_2O$-Al_2O_3-$nSiO_2$-mH_2O system are difficult to combustible and to flammable, and occupy a middle position between G1 and G2 in the combustibility group. As a result of the fire tests, the temperature of the flue gases did not exceed the critical value - above 260 [°C], the weight loss of the samples was in the range from 5.56 to 10.17 [%], and the burning rate did not exceed 0.0026 [kg/(m^2·s)]. Given the rather high margin of flue gas temperature, further fire tests are planned to be carried out according to EN 13823 in RICE Sweden.

1 Introduction

Wood is a natural, safe, durable and relatively inexpensive material that has long been used for the construction of various functional structures. Wood in the air-dry state has the disadvantage of low fire resistance and flammability. However, due to the fact that coal is formed on the wood surface during burning, it burns more slowly and with thermal conductivity 4 times lower than that of the wood itself, the loss rate of the working section of the wooden structure does not exceed 0.8 mm per minute, and when heated, it deforms into 3-4 times less compared to other materials. Therefore, wooden structures resist collapse in case of fire for a longer time, for example, than steel ones.

Ignition of wood from an open flame can occur at a temperature of about 210 [°C] and is accompanied by an increase in temperature. In the absence of an open source of heat (flame, sparks), ignition can occur when the wood is heated quickly (1-2 minutes) to a temperature above 330 [°C]. With prolonged exposure to heat, the ignition temperature of wood decreases to 150-170 [°C] [1].

The main condition for the continuation and development of independent burning of a lit wooden product is the excess of the amount of heat accumulated by its surface layers over the amount of heat transferred to space. That is, to maintain and spread combustion, it is necessary that the temperature of neighboring sections of structures is maintained above the flash point of the wood.

The smoother (without cracks) the pile surface of wooden products, the higher their heat-reflecting ability, the more difficult they light up. Sharp corners, protrusions, cracks reduce this ability.

Based on general ideas about the combustion mechanism [2], four groups of theoretically justified ways to reduce the combustibility of wood can be proposed.

The first group: impregnation of wood products with substances that would reduce the rate of thermal decomposition of wood or shift the direction of pyrolysis reactions towards the formation of smaller amounts of combustible gases.

The second group: the creation on the surface of wood products coatings from materials that would interfere with the fire of wood, its pyrolysis.

The third group: dilution of combustible gases with non-combustible gaseous substances, for example water vapor, carbon dioxide, nitrogen.

The fourth group: the creation of heat-reflecting coatings on the surface of wood products.

Consider the paints and varnishes related to the second group. From the review of works [3-7] it follows that paints that protect against fire are most often prepared on the basis of organic binders - dispersions of acrylic copolymers, epoxy resins, etc.; and also, on the basis of inorganic binders - phosphoric acid, potassium liquid (silicate) glass [8]. The composition of such paints includes: flame retardants, fireproof fillers, pigments and special additives. The most commonly used filler is ground expanded swollen vermiculite, perlite, talc, kaolin fiber, fluffy asbestos, and thermally expanding graphite [9]. Fire-retardant paints, in turn, are divided into two subgroups: intumescent and non-intumescent. Non-intumescent paints retain their thickness when heated. Intumescent paints, on the contrary, increase in size by 10–40 times when heated. In case of fire, intumescent fire-retardant paints decompose with heat absorption, emit inert gases and vapors, form a foam layer, which is a coked melt of non-combustible substances that block convective heat transfer to the surface to be protected, suppressing the flame.

The disadvantages of fire-retardant paints include their short shelf life (no more than 8-12 months), this is due to the use of flame retardants, and a limited limit of resistance to fire and temperatures.

As alternative methods of fire protection of wood, paints based on alkaline aluminosilicate binders are proposed, the theoretical foundations of which were developed by scientists of the school named after V.D. Glukhovsky at the Research Institute of Binders and Materials of the Kyiv National University of Construction and Architecture and its followers [10-13]. The basis for the production of such paints is the mechanism of directional synthesis in the $(Na, K)_2O$-Al_2O_3-$nSiO_2$-mH_2O binder system of zeolite and hydromica mica new formations capable of torotactic recrystallization into anhydrous phases without breaking the continuity of the crystalline skeleton with the formation of a porous layer of low thermal conductivity. The expansion of such paints is ensured by the removal of physically and chemically bound water, as well as the thermal degradation of fillers [14-22].

The aim of this work is to study the fire-retardant properties of wood paints on alkaline aluminosilicates-based.

2 Materials and Research Methods

For the manufacture of fire-retardant paints, an alkaline aluminosilicate binder was used with the ratio of the main oxides $Na_2O/Al_2O_3=1$, $SiO_2/Al_2O_3=6$ and $H_2O/Al_2O_3=20$ [10, 11, 17]. Functional fillers, pigments were introduced into the composition of paints. The polymer dry matter content did not exceed 1%. Paints were manufactured in an industrial dissolver under the conditions of Geofip LLC. Paints were applied to wooden samples of pine wood with dimensions of 150x60x30 [mm] and a moisture content of 12 [%] in two layers. The average coating thickness was 125 [μm]. Before firing tests, painted wood samples were thermally stabilized according to the requirements of the standard.

The study on determining the combustibility group of wood treated with the proposed coating was carried out in accordance with the current normative base. The essence of the test method for the experimental determination of the group of heavy and combustible solids and materials according to the influence of the sample is located in the ceramic tube of the OTM installation, the flame of the burner with the given parameters (the temperature of the gaseous combustion products at the exit from the ceramic tube is 200 [°C± 5°C]) In the course of experimental studies, the maximum increase in the temperature of the gaseous combustion products(Δt) and the sample mass loss (Δm) are recorded. According to test results, materials are classified as: − heavyweight − $\Delta t < 60$ [°C] and $\Delta m < 60$ [%]; − combustible − $\Delta t \geq 60$ [°C] or $\Delta m \geq 60$ [%].

The flammability group of paints was determined according to the requirements of DSTU B V.2.7-19-95 (Table 1).

Table 1. Combustibility groups

Combustibility groups of materials	Flammability parameters			
	Flue gas temperature T, [°C]	The degree of damage along the length S_L, [%]	The degree of damage by weight S_m, [%]	Duration of self-burning t_{sb}, [sec]
G1	≤ 135	≤ 65	≤ 20	0
G2	≤ 235	≤ 85	≤ 50	≤ 30
G3	≤ 450	> 85	> 50	≤ 300
G4	> 450	> 85	> 50	> 300

3 Discussions of Results

As can be seen from fig. 1, during the test for 300 seconds, the temperature of the flue gases of the investigated paints did not exceed the critical values Tcr = 260 [°C]. The mass loss [%] of the samples was, respectively, for red paint - 10.17, white - 6.25 and black - 5.56.

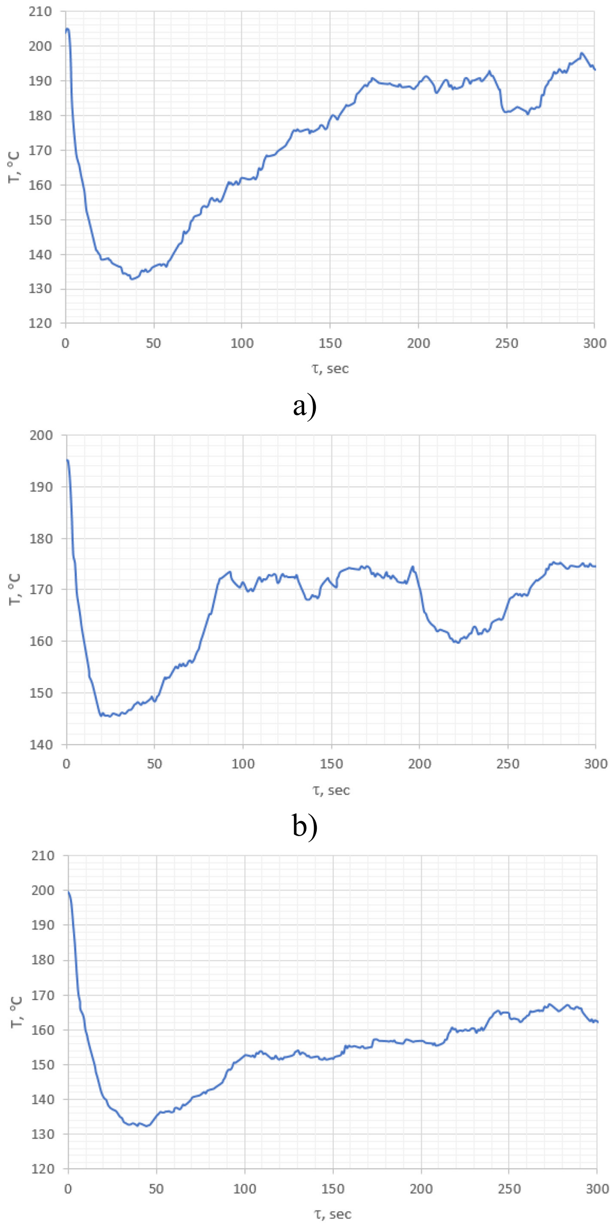
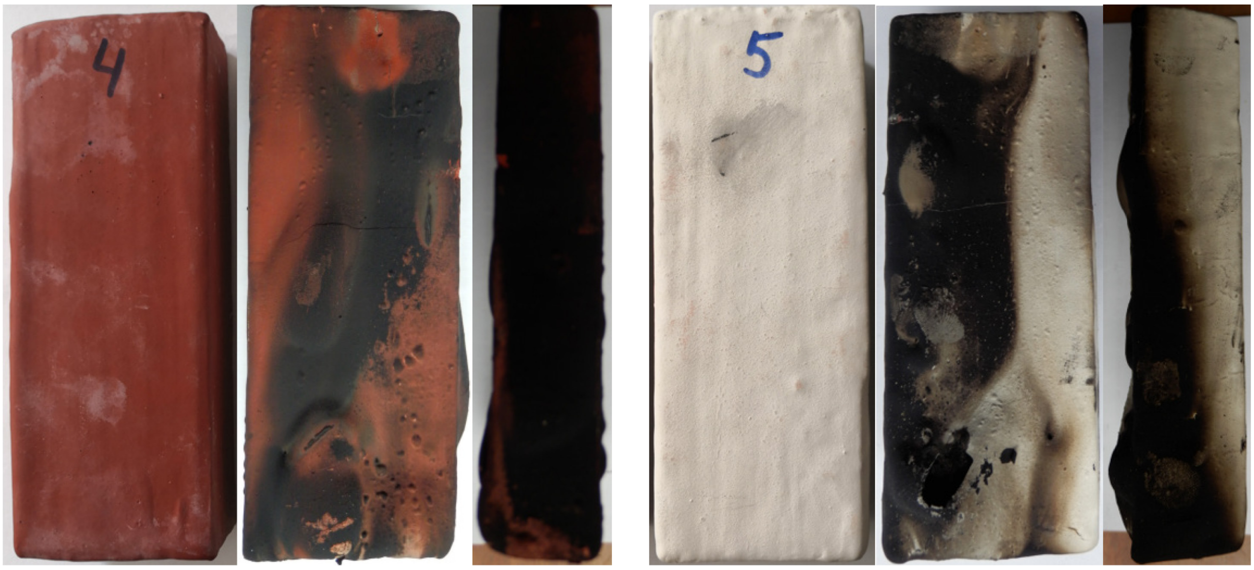


Fig. 1. Dependence of the temperature of flue gases on the time of testing paints for wood:
a - red, b - white; c- black

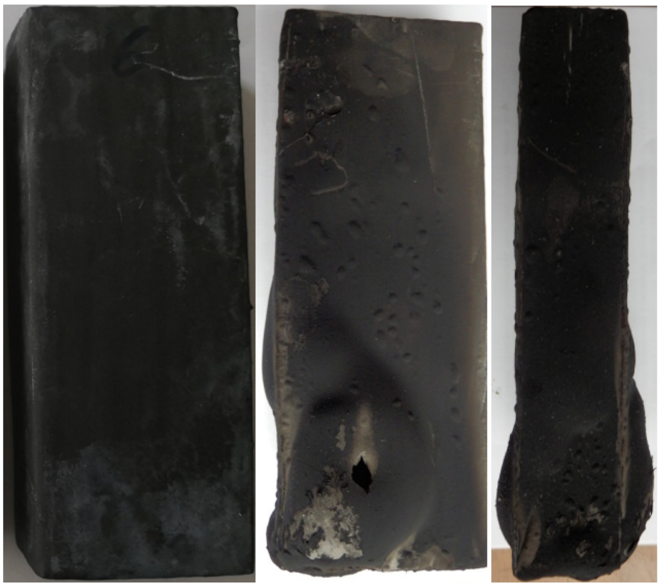
After fire tests, pine wood did not ignite (Fig. 2, b, c, e, f, h, i). Insignificant destruction of the continuity of the swollen paint of white and black color, as well as their insignificant independent burning during 0.5 and 1 [sec].

The developed paint compositions contribute both to the modification of the surface of pine wood and to self-extinguishing when exposed to fire.

Analyzing the kinetics of changes in the temperature of flue gases, it can be assumed that the developed compositions of fire-retardant paints are able to resist the effects of fire for a longer time.



a) b) c) d) e) f)



g) h) i)

Fig. 2. Appearance of images of paints on wood before (a, d, g) and after fire tests (b, c, e, f, h, i)

According to the results of fire tests, the developed compositions of fire-retardant paints based on alkaline aluminosilicates can be classified as difficult to combustible and to flammable (Δt <60 [°C] and Δm <60 [%]) and difficult to ignite, since the critical temperature of the flue gases was not reached during the test.

According to the combustibility group, paints occupy an intermediate rise between G1 and G2 according to only one criterion - the temperature of the flue gases (Table 2).

Table 2. The results of fire tests of paints

Flammability parameters	Color of paints		
	red	white	black
Flue gas temperature T, [°C]	196	175	167
The degree of damage along the length S_L, [%]	0	0.5	1
The degree of damage by weight S_m, [%]	10.17	6.25	5.56
Duration of self-burning t_{sb}, [sec]	0	0	1
Combustibility groups	G1/G2	G1/G2	G1/G2

According to the data of [16], for the studied fireproof paints based on alkaline aluminosilicates, the standard burning rate was calculated, the values of which do not exceed 0.0026 [kg/(m^2·s)].

Summary

As a result of the fire tests, it was found that the developed compositions of fire-retardant mineral paints on an alkaline aluminosilicate binder in the $(Na, K)_2O$-Al_2O_3-$nSiO_2$-mH_2O system are difficult to combustible and to flammable, and occupy a middle position between G1 and G2 in the combustibility group. As a result of the fire tests, the temperature of the flue gases did not exceed the critical value - above 260 [°C], the weight loss of the samples was in the range from 5.56 to 10.17 [%], and the burning rate did not exceed 0.0026 [kg/(m^2·s)]. Given the rather high margin of flue gas temperature, further fire tests are planned to be carried out according to EN 13823 in RICE Sweden.

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